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RESEARCH ON ATMOSPHERIC ATTENUATION OF INFRARED RADIATION

Howard T. Betz

Technical Note

The University of Chicago

LABORATORIES FOR APPLIED SCIENCES

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FOREWORD

This technical note is a brief review of first tests of a thermit standard radiation source both on the ground and on tethered balloons.

Principal contributors to this work were Howard Betz, Lucien M. Biberman, Richard Kauth, Joseph Jezewski and William Six.

Respectfully submitted,
LABORATORIES FOR APPLIED SCIENCES

Howard T Betz

Howard T. Betz
Senior Research Physicist

Approved:

Lucien M. Biberman
Associate Director

1. INTRODUCTION

The purpose of this program is to obtain the spectral transmission characteristics of the atmosphere through a variety of moderately long slant paths. In general, the description of the project and its methods is described in LAS-TN-E173-1, 2, 3, and 4. This report briefly summarizes the methods and results obtained from an initial series measurements at Cape Canaveral.

2. DESCRIPTION OF EQUIPMENT

A brief description of the method and equipment follow:
The system consists of two separate units, (1) the infrared source and (2) the radiation detection system.

1. The source is a 10-inch diameter hollow graphite sphere which is filled with Thermit. The temperature was to begin at 2800°F and cool to 900°F after 30 minutes. The source is to be carried by balloons (either tethered or free) and the temperature telemetered. Temperature measurement is made with a thermocouple and the electronic readout system was capable of approximately 1% overall accuracy.

2. The radiation detection system consists of a Perkin-Elmer monochromator with a 12-1/2 diameter f/5 collector. The slit is filled by a calcium fluoride cylindrical lens. Detectors used are PbS and indium antimonide covering a range of 1.5 to 5.0 microns. The entire system was mounted on a Mk-51 gun director and the source was manually tracked. In order to allow for horizontal tracking error the system was nodded in azimuth through 1/2 degree with a 5-second period. As the image crossed the slit the peak signal was detected and recorded. Lead sulfide detectors were placed at top and bottom of the entrance slits. Coincidence signals (which were recorded) indicated if the slit was filled and if the image actually crossed the slit. A third lead sulfide detector located at the side of the slit was used to reset the peak detector on each nod.

A four-channel Sanborn recorder was used to record the received power, coincidence, wavelength and time.

It was originally intended that a Perkin-Elmer double-pass monochromator with internal chopper would be used. However, the pulse introduced by sweeping the image across the slit was detected by the level detector giving an erroneous signal. (In the double-pass instrument, energy is present from both the single-pass and double-pass at the entrance slit. Since only the double-pass energy is chopped by the internal chopper the single-pass energy is undetected. However, when the source is modulated the single-pass energy is also detected.) The instrument was converted to a single-pass monochromator with an external chopper.

Chopper frequency was chosen at 240 cycles/sec with an amplifier bandpass of 10 cycles. Severe difficulty was experienced in the use of the indium antimonide detector. The cell was extremely noisy as well as exhibiting very low sensitivity. It was finally decided to continue the tests using only the lead sulfide detector and delay any additional study until the problem could be examined in the laboratory. Subsequent tests have indicated that some of the difficulty can be attributed to the excessive nonuniformity of sensitivity over the surface of this detector.

3. USE OF THE EQUIPMENT

In order to calibrate the radiation measuring equipment a black body at $1000^{\circ}C$ with a 1/4 inch aperture was placed at 200 ft distance. A lead sulfide detector was used. A photograph of the Sanborn record is shown in Fig. 1. The record shows clearly the spectrum of the black body, the coincidence marks, and the wavelength drum markers. The time signal is not shown here since the pulses were so rapid that they would not have been resolved and since the source is at constant temperature they are not required.

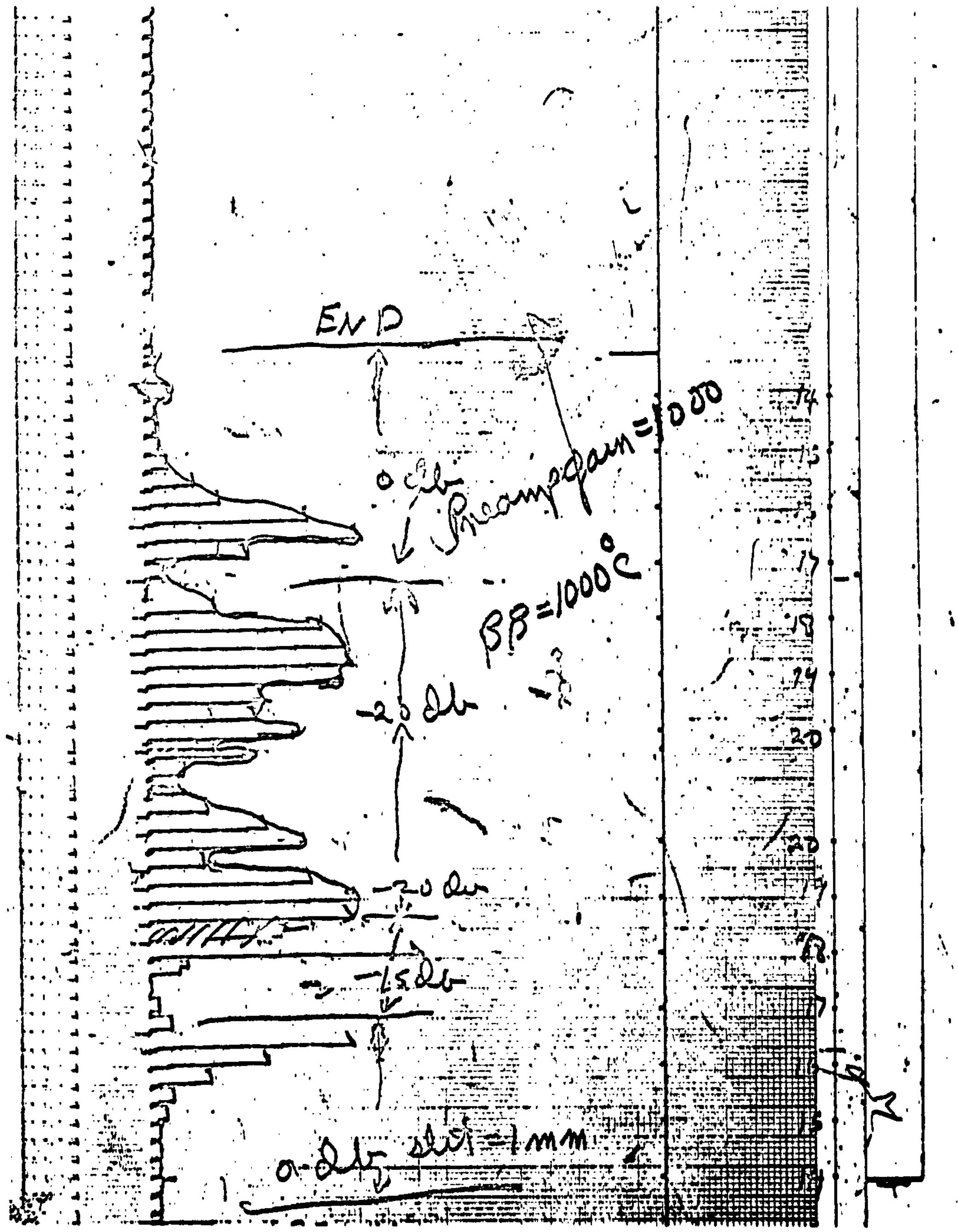


Figure 1. Typical calibration record against 1000°C blackbody

Reduction of this data results in the signal voltage as a function of spectral irradiance at the collector.

A similar recording is made for the Thermit radiator and is shown in Fig. 2. In order to resolve the time marks the paper drive was speeded up (10 times) resulting in the spectrum being very long so only a small portion is shown in the illustration.

Figure 3 shows the spectrum obtained from a 1000°C black body 1/4 inch diameter aperture 200 ft from the collector using the lead sulfide detector. This is a reduction of data from Fig. 1 and gives volts as a function of wavelength. The slit width was left constant at 1 mm (as in all other traces) and the corresponding spectral bandwidth varies from 0.098 micron at 1.5 microns to 0.007 micron at 3.5 microns.

Figure 3 also shows a similar curve for the radiator fired 2 March from the test stand at the Cape Weather station. The temperature data for this radiator is shown in Fig. 4. This data was taken at four points with an optical pyrometer (hot filament type) and with a thermocouple in the well. A photograph is shown in Fig. 5. Time zero (firing of the radiator) 2132 hours EST.

Assembly of the balloons and harness was begun on 24 February. Mr. Jalbert, the supplier of balloons was on hand to assist. In order to lift the package, three balloons were required, two J-9D balloons were harnessed side-by-side with lightweight poles with a bridle connecting them to the package. The flying line consisting of 3000 ft of 1/4 inch nylon rope was fastened to the bottom of the package with 15 feet of 1/8 inch steel cable. The third balloon a J-9 was connected to the line 600 ft below the payload and carried the weight of the line. The system was first flown on 29 February in daylight. Following the daylight flight and some readjustment of the harnessed balloons, two successful nighttime flights were made.

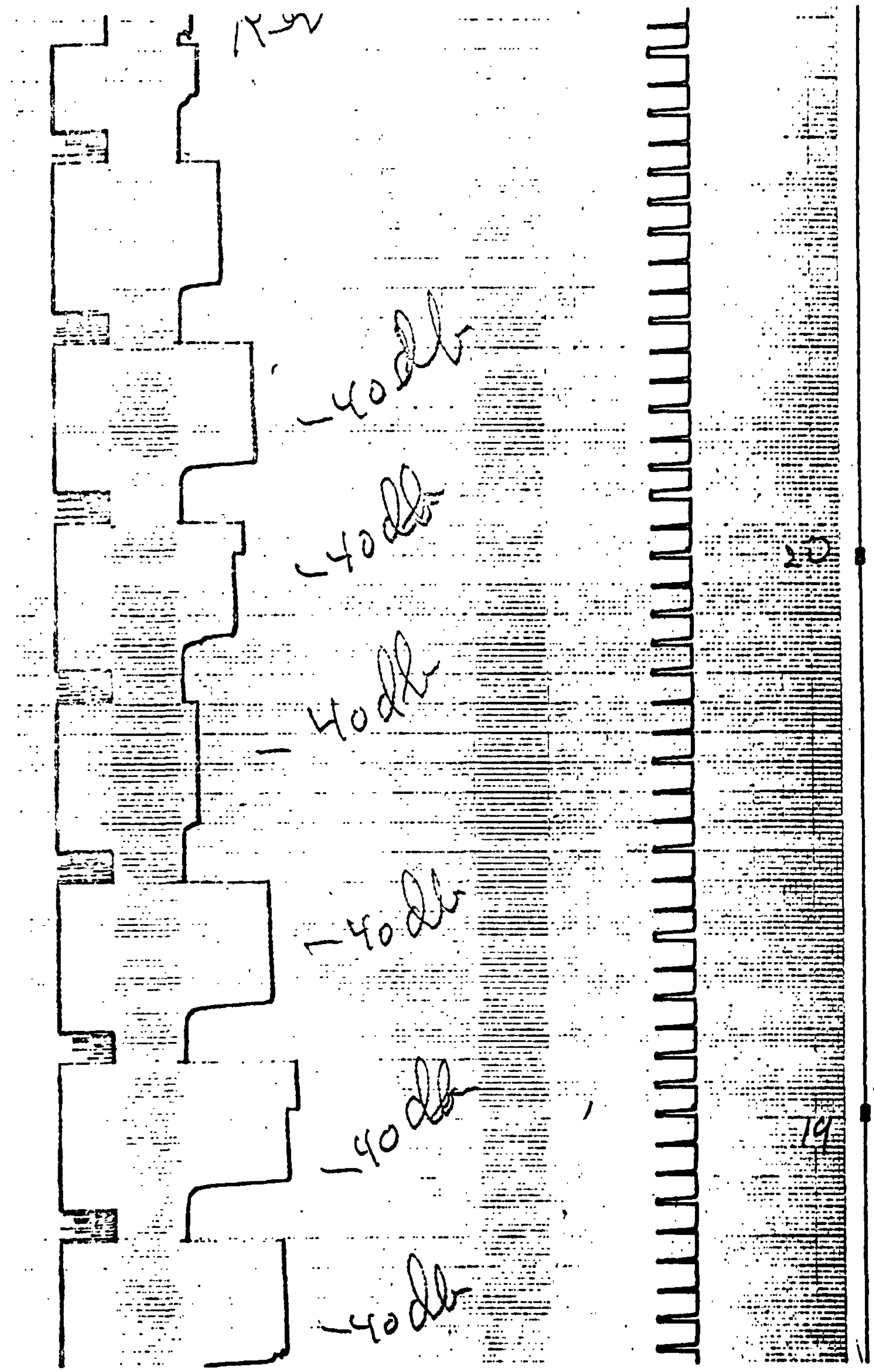


Figure 2. Typical record from graphite crucible

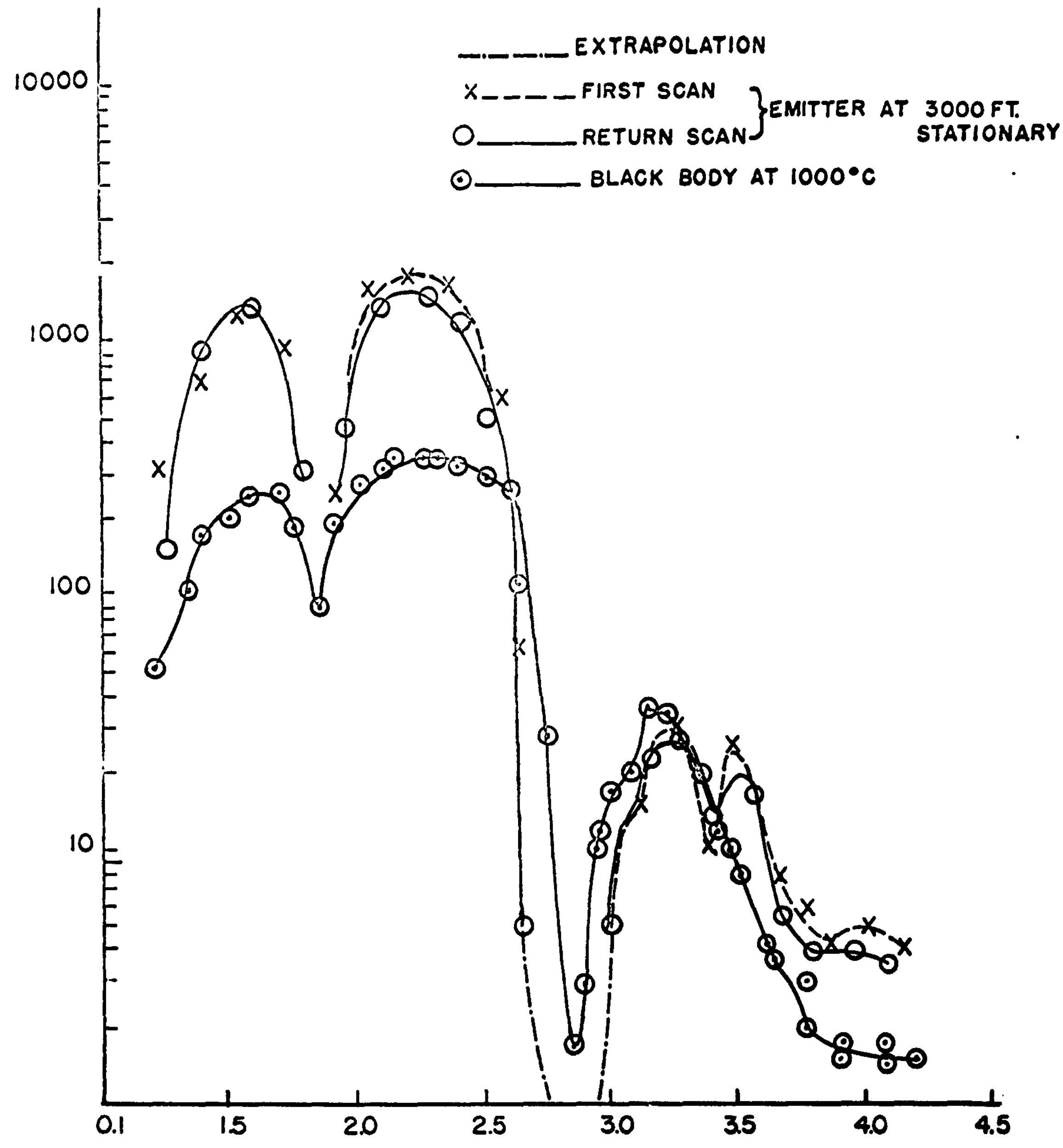


Figure 3. Spectra of blackbody and ground based emitter.

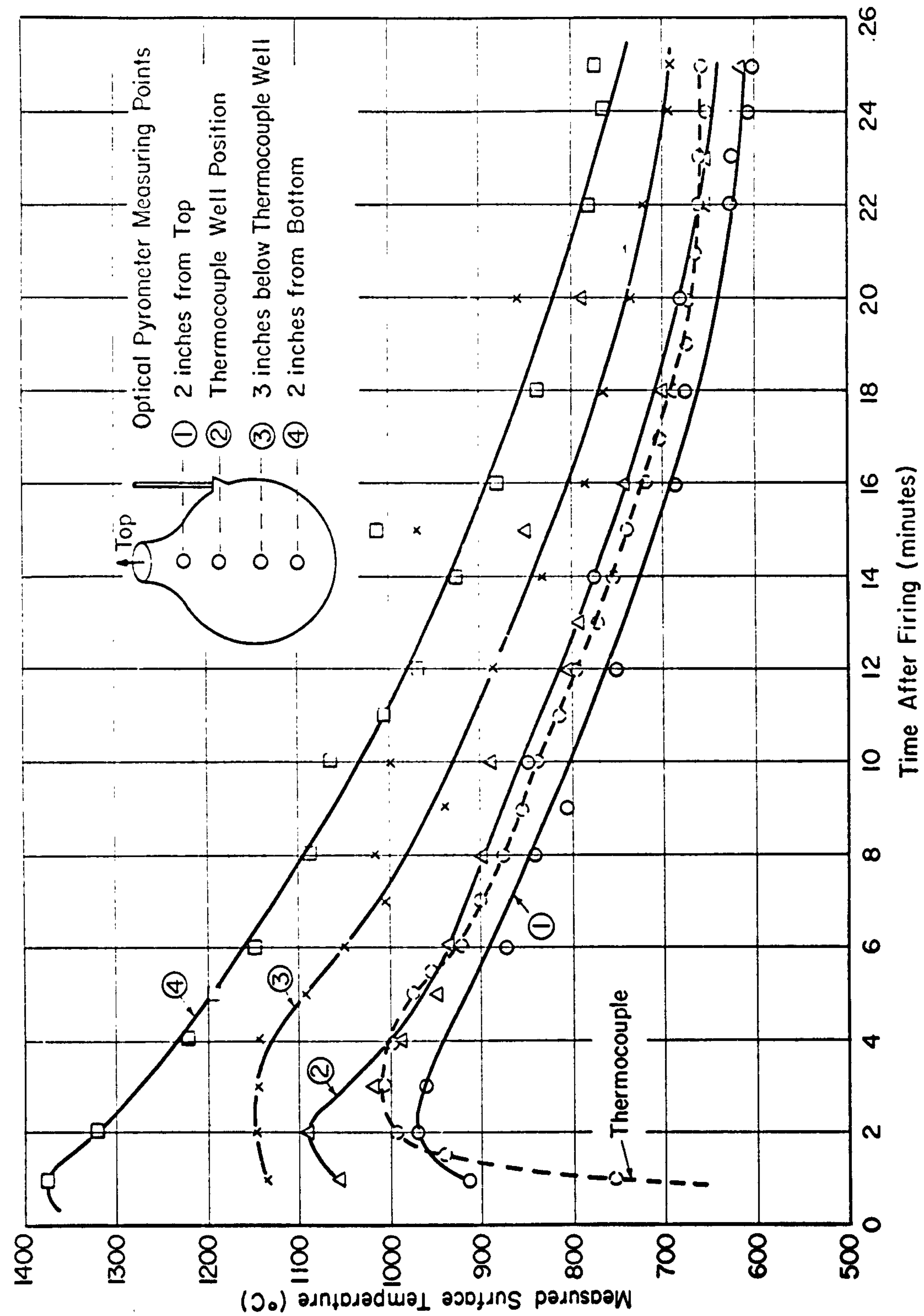
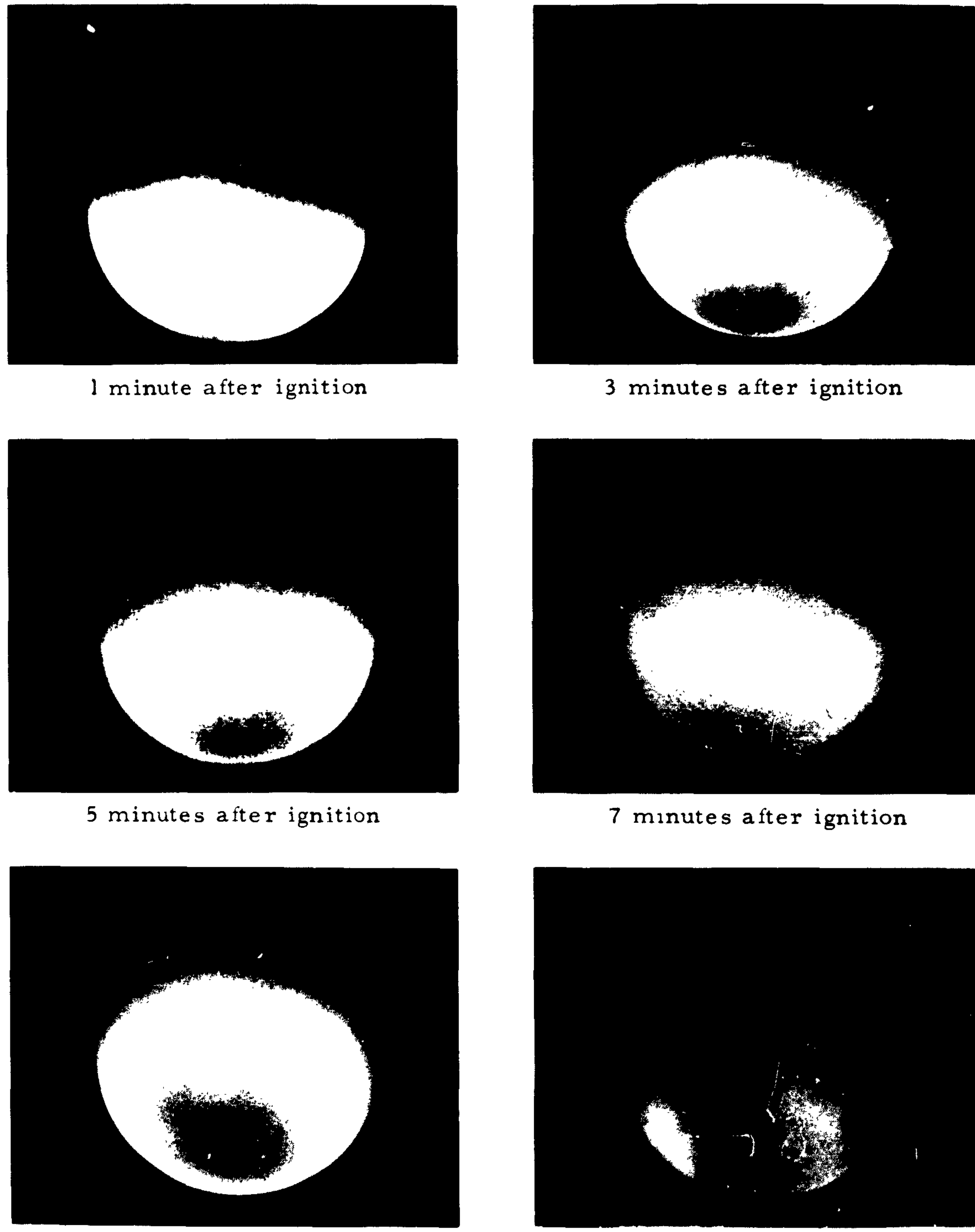


Figure 4. Temperature curves of an IR luminous radiator



1 minute after ignition

3 minutes after ignition

5 minutes after ignition

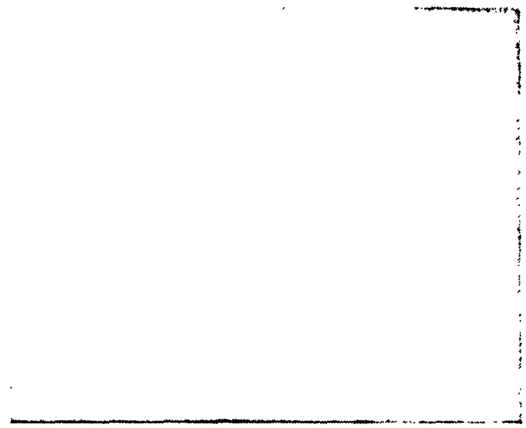
7 minutes after ignition

10 minutes after ignitior

13 minutes after ignition

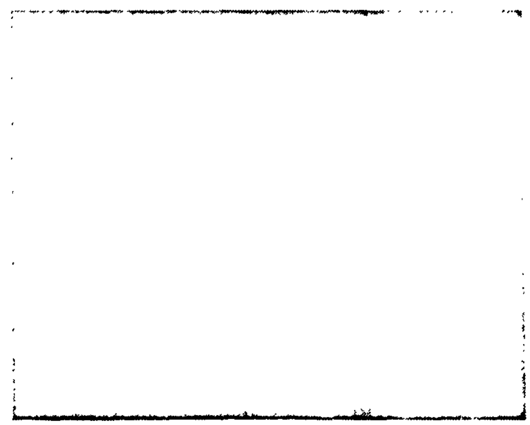
Figure 5. Luminous radiator photographed during nighttime tests

1 minute after ignition

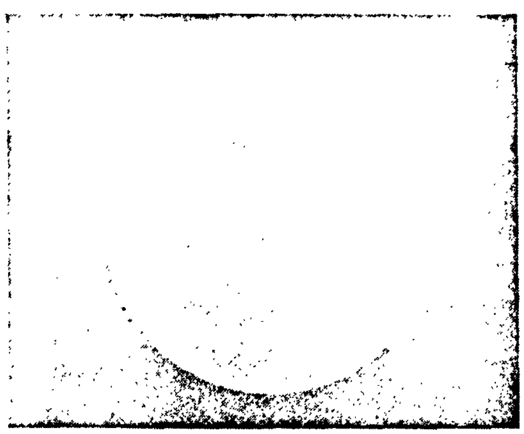


3 minutes after ignition

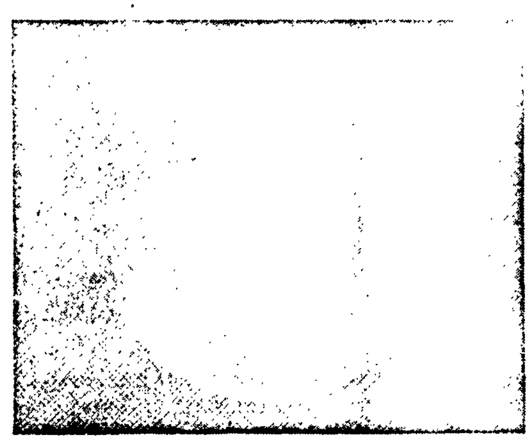
5 minutes after ignition



7 minutes after ignition



10 minutes after ignition



13 minutes after ignition

Figure 5. Luminous radiator photographed during nighttime tests

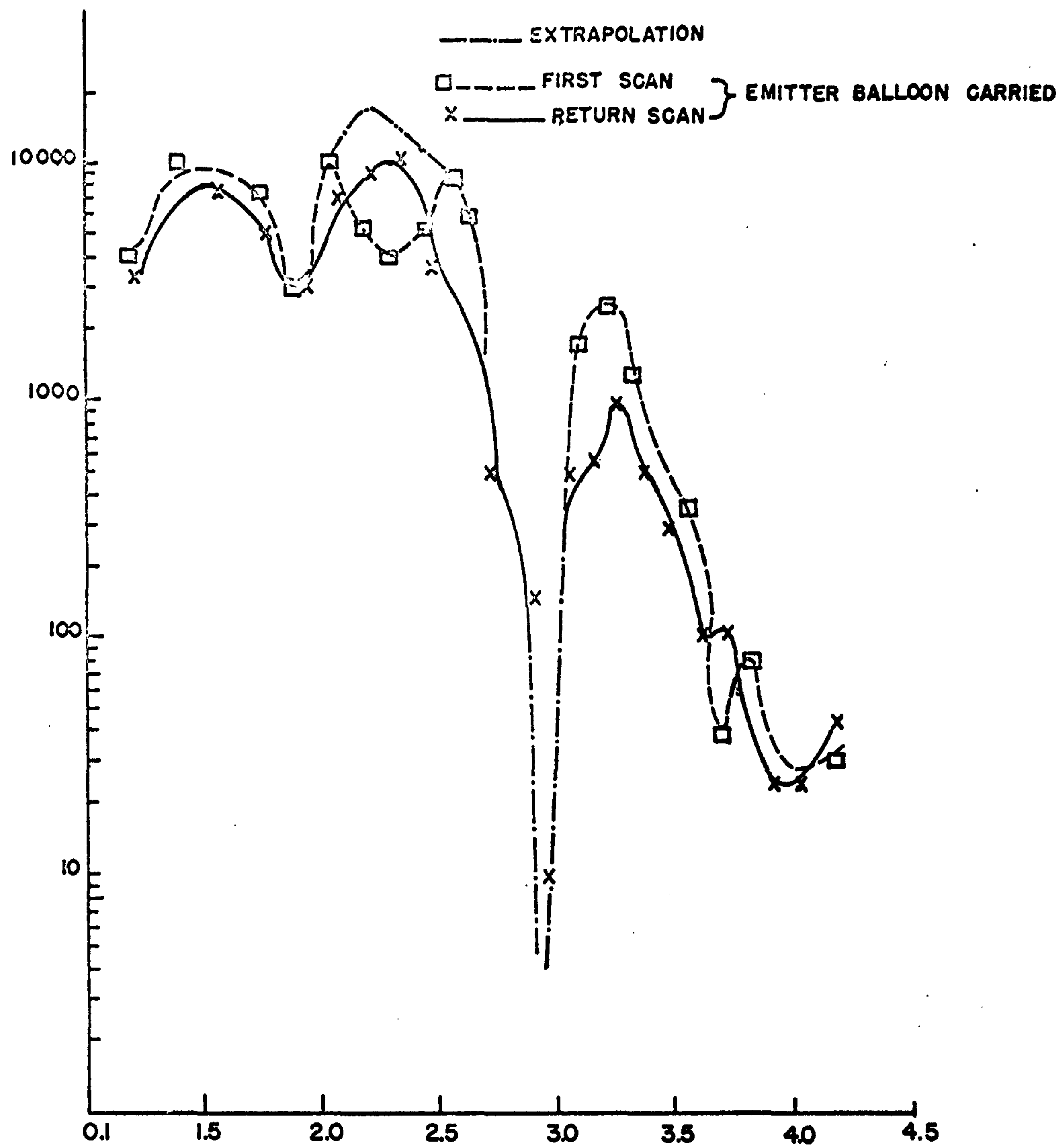


Figure 6. Spectrum of balloon carried emitter.

The daytime flight was made primarily to familiarize the balloon crew with handling the balloons and to permit observations of the action of the balloons, harness and flying lines. No usable radiation data was obtained because of the high level of lighted sky background.

The first nighttime flight 29 February, 1930 hour did not supply much useful radiation data because of the fogging of all optical surfaces. Useful telemetry data was however obtained. The second night flight 4 March at 2000 is also plotted on Fig. 6.

5. RESULTS

The data from this series of measurements is shown in Fig. 3 and Fig. 6. No attempt is made to dignify the data by tabulating in more formal tables or by ascribing absolute values to these results although all necessary functions of calibration have been performed. The reasoning leading to this decision is based upon the following facts:

1. The source was not a uniform source over its projected area (see Figs. 4 and 5). The variation of temperatures viewed by our equipment was as much as 450°C. As such the source as a "standard" was meaningless without a large number of temperature time plots which for the precision required are completely beyond operational feasibility.

2. In the case of the tethered flight these laboratories have not yet received data concerning balloon position and thus slant range from the range data center. Thus values of HR^2 are not computable.

3. The methodology of our operation makes unnecessary the calculation of intermediate values such as spectral detectivity for our receiver. Since we calibrate against a known black body and measure using a known black body all usual corrections are self cancelling. This is one of the technical

beauties of the method. It merely demands frequent checks against a standard black body before and after each run. The use of standard black bodies at approximately the temperature of lofted black body source further simplifies the method.

4. The radiant intensity of the source is aspect dependent. Precise aspect data of the lofted source cannot logically be expected from a freely swinging balloon-borne source. Thus, the source radiant intensity is not known.

For the above reasons further computations were felt to be without meaning.

6. THE SOURCE AND ASSOCIATED PROBLEMS

The aspect dependence and reproducability of aspect dependence of the source and its correction is the subject of a large volume of separate correspondence. The problem is serious. Failure to solve this problem will make this methodology inapplicable for the problem at hand.

It is hoped that decisions on the source aspect sensitivity problem can be reached in the next week or two. In the interim, attention is being given to the possibility of making aspect corrections. These calculations are complex and applicable to the free balloon case only.